# Effect of grain straw and furrow irrigation stream size on soil erosion and infiltration

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*ABSTRACT: Loose straw was placed by hand in furrows of a bean field at the rate of 1.5 kg/100 (1 pound/100 feet) to test its effect on soil erosion and infiltration at two flow rates. Straw significantly ($\alpha = .01$) reduced sediment losses and increased infiltration at both flow rates on the Portneuf silt loam soil. After 6 hours of a 12-hour irrigation, the straw furrow appeared to be wetted enough that the irrigation water could have been turned off. A 12-hour irrigation was required to wet the no-straw furrows to the plant row. Straw increased infiltration 50% in 10 hours. There were 98 and 47 kg (216 and 104 lbs) net sediment yields during six irrigations from the no-straw and straw-treated furrows, respectively, at the lower flow rates and 224 and 66 kg (494 and 146 lbs), respectively, at the high flow rates. Straw reduced net sediment yields 52 and 71% during the irrigation season at the low and high flow rates, respectively.*

PROPER use of crop residue is one of the most effective tools to solve soil erosion problems (*5*). Corn residue in irrigation furrows can eliminate erosion and runoff water turbidity and increase infiltration (*2*). Researchers also have found that small amounts of straw effectively reduce furrow erosion.

In one study infiltration increased about 90% when 13.4 t/ha (6 tons/acre) of straw was rototilled into the surface 15 cm (6 inches) of soil (*6*). In that test, on Warden fine sandy loam (coarse-silty, mixed, mesic Xerollic Canborthids) with a 3% slope, erosion was severe in the clean furrows and negligible in the straw furrows.

Even under center-pivot sprinkler systems, small basins, surface mulch, or incorporating plant material into the soil reduced runoff and increased infiltration (*1*).

Furrow stream size and cultivation are also important factors affecting soil erosion. Miller and Aarstad (*7*) found that cultivating the furrow bottom on Warden fine sandy loam with a 3% slope caused serious erosion when the furrow inflow rate was 6 liters/minute (1.6 gallons/minute) or more. When 6.7 t/ha (3 tons/acre) and 13.4 t/ha (6 tons/acre) of straw were placed in the furrows, erosion was eliminated at all inflow rates up to 8 liters/minute (2.1 gallons/minute). The furrows were 59 m (194 feet) long.

Berg and Carter (*4*) found that erosion increased sharply on row-cropped fields when slopes exceeded 1%. They also found that sediment leaving furrow-irrigated fields can be reduced by (a) reducing furrow stream size at the tail end, (b) avoiding irrigation of row crops on steep slopes, (c) keeping the tailwater ditch shallow and the water in it moving slowly, (d) installing tailwater control systems, and (e) alternate-furrow irrigation.

Southern Idaho farmers irrigate row crops on steep slopes (2% and greater). Soil erosion and low infiltration are problems. Drastic erosion occurs on many fields with average slopes as low as 1%. My study sought to evaluate the effects of placing straw in furrows on erosion and infiltration at different furrow inflow rates.

## Study methods

The study was conducted on Portneuf silt loam (Durixerollic Calciorthid) planted to dry beans at the Snake River Conservation Research Center near Kimberly, Idaho. I collected data at five sampling sites in different furrow-length segments down each of eight furrows having a total length of 146.2 m (480 feet). Irrigation water entered each furrow from gated pipe (Figure 1) and traveled 15.2 m (50 feet) to the first sediment-water sampling site, a small trapezoidal measuring flume. The second, third, and fourth sampling sites were spaced at 30.4-m (100-foot) furrow length segments from the first site. The fifth and last sampling site was 39.6 m (130 feet) downstream from site 4. Small trapezoidal flumes measured the water leaving each furrow at sampling site 5. Water entering site 1 was the water measured "IN" to length segment 1. Water entering site 2 was the "OUT" for furrow length sediment 1 and "IN" for furrow length segment 2 and so on until it passed site 5 (the end of the furrow).

There were two straw and two no-straw furrows at two flow rates. Loose straw was placed by hand in the bottom of the straw-treated furrows at the rate of 1.5 kg/100 m (1 pound/100 feet) prior to the first irrigation. Straw was again placed in the furrows after the third irrigation, which took place after the beans had been cultivated.

The furrows, spaced 112 cm (44 inches) apart, were irrigated with water from a large storage pond. This water was clear, and I assumed it contained no sediment.

Flow rates varied from irrigation to irrigation but were held constant during each irrigation. Low flow rates for the season averaged 10.3 liters/minute (2.7 gallons/minute) and 13.2 liters/minute (3.5 gallons/minute) for the no-straw- and straw-treated furrows, respectively. High flow rates for the season averaged 15.0 liters/minute (4.0 gallons/minute) and 15.8 liters/minute (4.2 gallons/minute) for the no-straw- and straw-treated furrows, re-

Figure 1. Straw reduced erosion as water entered the furrows from gated pipe.

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spectively. Because straw slowed the water flow, the average low flow and high flow rates were increased by 3 liters/minute (.8 gallons/minute) and 1 liter/minute (.26 gallons/minute), respectively, in the straw-treated furrows so the water would reach the end of all furrows within 30 minutes.

I measured six 10-hour irrigations during the growing season. Water flow was measured as water entered and left each furrow, and 1-liter (.26-gallon) samples were collected to determine sediment concentration and yield at each sampling site. I collected three samples during each of the first three irrigations and four samples during each of the last three irrigations. The first sampling began about 15 to 30 minutes after the first runoff water left the furrow. Two to three hours elapsed between each sampling. All samples were transported to the laboratory immediately after collection where they were vacuum filtered through preweighed Whatman 50 hardened filter papers. Filters containing sediment were dried, weighed, and sediment concentrations and yields calculated.

## Results and discussion

Comparing no-straw furrows at two flow rates, an average 25 cm (9.8 inches) of water was applied at the average low flow rate of 10.3 liters/minute (2.7 gallons/minute) during six irrigation periods. Of the total applied, 14 cm (5.5 inches) or 55% left each furrow (Table 1). The remaining 11 cm (4.3 inches) or 45% infiltrated. An average 37 cm (14.6 inches) of water was applied at the average high flow rate of 15.0 liters/ minute. Of the total applied, 21 cm (8.3 inches) or 57% ran off, while 16 cm (6.3 inches) or 43% infiltrated.

Figure 2. The wetting front of a straw and no-straw furrow after 6 hours of a 12-hour irrigation.

Infiltration on the no-straw furrows increased by 45% when the average flow increased from 10.3 to 15.0 liters/minute (2.7 to 4.0 gallons/minute). At the higher flow rate, infiltration increased because the wetting perimeter was greater.

There was 34% more runoff [7 cm (2.8 inches)] and 56% more erosion [126 kg (278 pounds)] in no-straw furrows at high flow than at low flow.

Comparing straw-treated furrows at two flow rates, an average 31 cm (12.2 inches) of water was applied during six irrigations at the average low rate. An average of 11 cm (4.3 inches) or 34% ran off each furrow; 20 cm (7.9 inches) or 66% infiltrated. In contrast, an average 39 cm (15.4 inches) of water was applied during six irrigations at the high flow rate. An average of 19 cm (7.5 inches) or 48% ran off each furrow; 20 cm (7.9 inches) or 52% infiltrated. The straw-treated furrow significantly increased infiltration and high flow significantly increased runoff ($\alpha = .01$ level).

With the straw treatment, the total amount of water infiltrated was essentially equal at both flow rates (Table 1). The wetted perimeter of straw-treated furrows visually increased about equal amounts regardless of flow rates used. Although infiltration on the straw-treated furrows was about the same at both flow rates, runoff was almost twice as high at the high flow rate (42%). Soil loss at the high flow rate was 29% greater.

**Table 1. Average total flow, runoff, and infiltration during six irrigations at two flow rates in furrows with and without straw, planted to dry beans, 1982.***

| | *No-straw* | | | | *Straw* | | | |
|---|---|---|---|---|---|---|---|---|
| | *Low Flow (10.3 liters/ minute)* | | *High Flow (15.0 liters/ minute)* | | *Low Flow (13.2 liters/ minute)* | | *High Flow (15.8 liters/ minute)* | |
| | *In* | *Out* | *In* | *Out* | *In* | *Out* | *In* | *Out* |
| | *liters* | | | | | | | |
| Flow | | | | | | | | |
| Irrigation 1 | 6,184 | 3,036 | 7,812 | 5,289 | 11,350 | 4,293 | 9,450 | 2,724 |
| Irrigation 2 | 5,098 | 3,298 | 7,503 | 3,784 | 7,225 | 2,196 | 8,192 | 3,038 |
| Irrigation 3 | 5,062 | 2,631 | 8,624 | 5,308 | 6,372 | 2,150 | 8,483 | 3,802 |
| Irrigation 4 | 6,184 | 3,856 | 9,443 | 5,610 | 6,339 | 1,750 | 8,773 | 4,810 |
| Irrigation 5 | 6,530 | 3,815 | 9,068 | 4,755 | 6,138 | 1,690 | 10,441 | 5,702 |
| Irrigation 6 | 7,783 | 3,686 | 11,504 | 5,936 | 8,243 | 3,590 | 11,411 | 7,174 |
| Total flow | 36,841 | | 53,954 | | 45,667 | | 56,750 | |
| Runoff | | | | | | | | |
| (liters) | | 20,322 | | 30,682 | | 15,669 | | 27,250 |
| (%) | | 55 | | 57 | | 34 | | 48 |
| Infiltration | | | | | | | | |
| (liters) | | 16,519 | | 23,272 | | 29,998 | | 29,500 |
| (%) | | 45 | | 43 | | 66 | | 52 |

*Flow rates are seasonal averages.

Farmers consider a dry bean crop adequately irrigated when the wetting front moves only a few inches beyond the plant row. In this study the straw furrows appeared to have been wetted adequately after 6 hours of irrigation (Figure 2). However, a 12-hour irrigation was required to wet the no-straw furrows adequately. After a 10-hour irrigation, about 50% more water infiltrated in the straw-treated furrows than in the untreated furrows.

Straw significantly ($\alpha = .01$) reduced sediment concentration in the runoff water at both flow rates (Table 2), but the average sediment concentrations did not significantly vary with flow rates. With the straw treatment, sediment concentrations in the runoff water for each irrigation declined 50% to 15% at the low flow and from 33% to 8% at the high flow rate.

**Table 2. Sediment concentrations in five length segments along the furrows during six irrigations at two flow rates in furrows with and without straw, planted to dry beans, 1982.***

| | | *Average Sediment Concentration (ppm)* | | | |
|---|---|---|---|---|---|
| | | *No-straw* | | *Straw* | |
| *Site Number* | *Distance from Inflow (m)* | *Low Flow (10.3 liters/ minute)* | *High Flow (15.0 liters/ minute)* | *Low Flow 13.2 liters/ minute)* | *High Flow (15.8 liters/ minute)* |
| 1 | 15.2 | 3,620 | 3,082 | 670 | 972 |
| 2 | 45.6 | 7,825 | 6,805 | 1,116 | 1,130 |
| 3 | 76.0 | 5,412 | 5,172 | 1,140 | 434 |
| 4 | 106.4 | 2,945 | 4,301 | 658 | 350 |
| 5 | 146.0 | 5,348 | 8,101 | 2,778 | 3,422 |
| Average | | 5,030 | 5,492 | 1,272 | 1,262 |

*Flow rates are seasonal averages.

Table 3 shows the net sediment and deposition pattern at the end of each furrow length segment for the no-straw- and straw-treated furrows at both flow rates. Sediment eroded from each furrow between the gated pipe and the first flume. At the low flow rate there was 122 kg (269 pounds) and 30 kg (66 pounds) eroded for the no-straw- and straw-treated furrows, respectively (Figure 1). Sediment eroded from these same furrows at the end of the first length segment was 114 kg (251 pounds) and 10 kg (22 pounds) for the no-straw- and straw-treated furrows, respectively.

At the high flow rate sediment yield was 144 kg (318 pounds) and 58 kg (128 pounds) from the no-straw- and straw-treated furrows, respectively, between the gated pipe and the first flume. At the end of the first furrow segment, at the high flow rate, sediment yield was 142 kg (313 pounds) and 6 kg (13 pounds) for the no-straw- and straw-treated furrows, respectively.

Further downfield there was a net sediment deposition at the end of furrow length segments 2 and 3 at all treatments and flow rates (Table 3). Deposition occurred in these furrow length segments because a decrease in slope reduced the water flow velocity, which in turn reduced the sediment carrying capacity of the irrigation water. Figure 3 compares no-straw- and straw-treated furrows about midfield. The no-straw furrow is eroded deep and narrow, which reduces the wetting perimeter. The straw treated furrow, however, is wider and shallower, which increases the wetting perimeter. Figures 4 and 5 show ground-level views from the bottom of these two furrows.

**Table 3. Total sediment entering and leaving each furrow length segment during six irrigations. The net sediment deposition is also shown at the end of each length segment in the furrows with and without straw, planted to dry beans, 1982.***

| Furrow Segment | | | Total Sediment (kg) | | | |
|---|---|---|---|---|---|---|
| | | | No-Straw | | Straw | |
| Length | Number | | Low Flow (10.3 liters/minute) | High Flow (15.0 liters/minute) | Low Flow (13.2 liters/minute) | High Flow (15.8 liters/minute) |
| 30.4 m | 1 | In | 122 | 144 | 30 | 58 |
| | | Out | 236 | 286 | 40 | 52 |
| Difference† | | | −114 | −142 | −10 | +6 |
| 30.4 m | 2 | In | 236 | 286 | 40 | 52 |
| | | Out | 143 | 209 | 35 | 16 |
| Difference† | | | +93 | +77 | +5 | +36 |
| 30.4 m | 3 | In | 143 | 209 | 35 | 16 |
| | | Out | 71 | 148 | 20 | 12 |
| Difference† | | | +72 | +61 | +15 | +6 |
| 39.6 m | 4 | In | 71 | 148 | 20 | 10 |
| | | Out | 98 | 224 | 47 | 66 |
| Difference† | | | −27 | −76 | −27 | −56 |
| Net sediment yield | | | −98 | −224 | −47 | −66 |

*Flow rates are seasonal averages.
†(− = net erosion, (+) = net deposition.

As water entered segment 4 on all treatments, the slope increased 0.4%. This increased flow velocity and, hence, erosion potential. Also, as water passed through the last 6.1 m (20 feet) in segment 4, the slope increased from 0.7% to 2%, which again increased the erosion potential. As a result, a significant amount of total sediment lost from the field came from the last segment ($\alpha = .01$). Applying straw to the last 6.1 m (20 feet) in segment 4 effectively reduced the erosion (Figure 6). Subsequent irrigations eroded the untreated furrow deeper, causing the erosion area to extend further up the field even from that shown in the untreated furrow.

Net sediment yield from the no-straw- and straw-treated furrows was 98 and 47 kg (216 and 104 pounds), respectively, at the low flow rates. At the higher flow rates net sediment yield was 224 and 66 kg (494 and 146 pounds) from the no-straw- and straw-treated furrows, respectively. Straw reduced net sediment yield 52% and 71% during the irrigation season at the low and high flow rates, respectively.

Figure 3. A mid-field view of a furrow with and without straw.

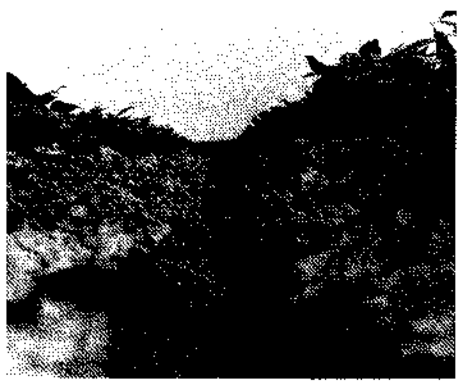

Figure 5. A ground-level view of the furrow without straw shown in figure 3. Erosion was narrow and deep.

Figure 4. A ground-level view of the straw-treated furrow shown in figure 3. Straw has dissipated the water's energy to erode.

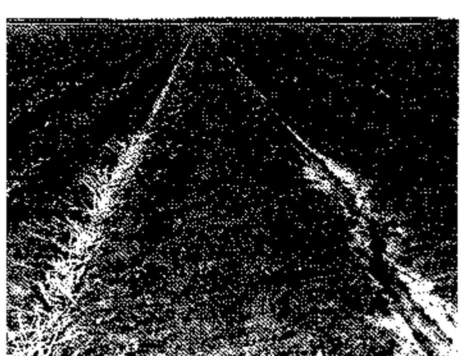

Figure 6. Straw reduced erosion on the convex-end (about 2% slope) of this bean field.

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